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B1T TPPA

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US 5300222 A

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(54) Abstract Title
Separator

(57) A separator is disclosed which separates recovered drilling mud for reuse from other associated borehole products. These products include a gas component, a liquid hydrocarbon component, a water based component (drilling mud), and a solid component. This mixture is fed into the separator 10 via a tangential inlet causing a cyclone to form in a first cylindrical section 14 which separates out the gas component and causes partial separation of the remaining components. These components travel down a second cylindrical portion 12 which affects further separation and allows passage of the relatively light hydrocarbon component through a side opening 34. The heavier components move further down the cylindrical portion 12 where they collect in a vessel 11, with drilled solids settling at the bottom of the vessel 1. The liquid hydrocarbon 23 and watery layers 24 are drained automatically.

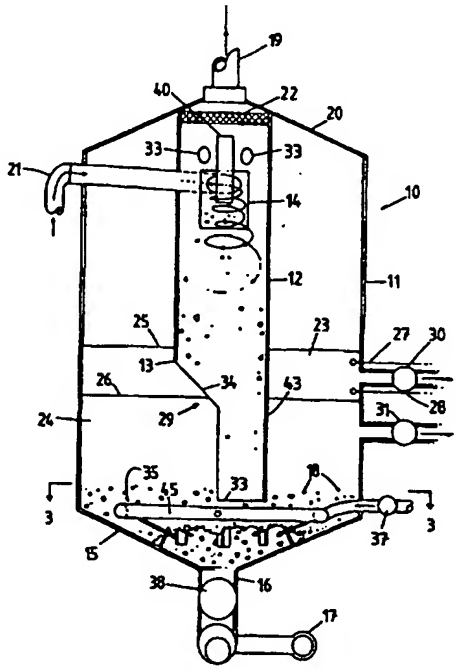

FIG.2

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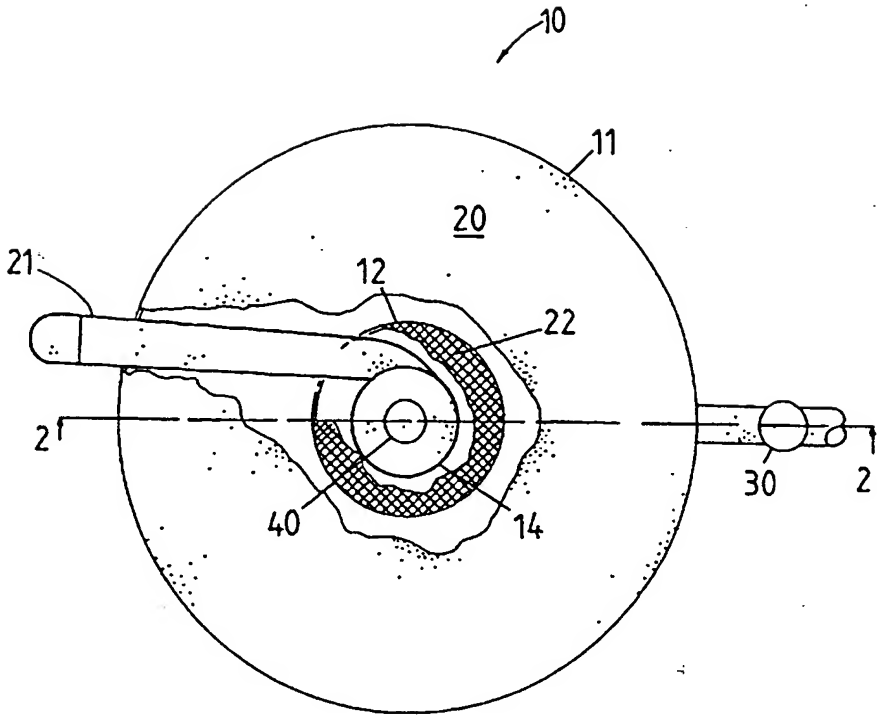

FIG. 1

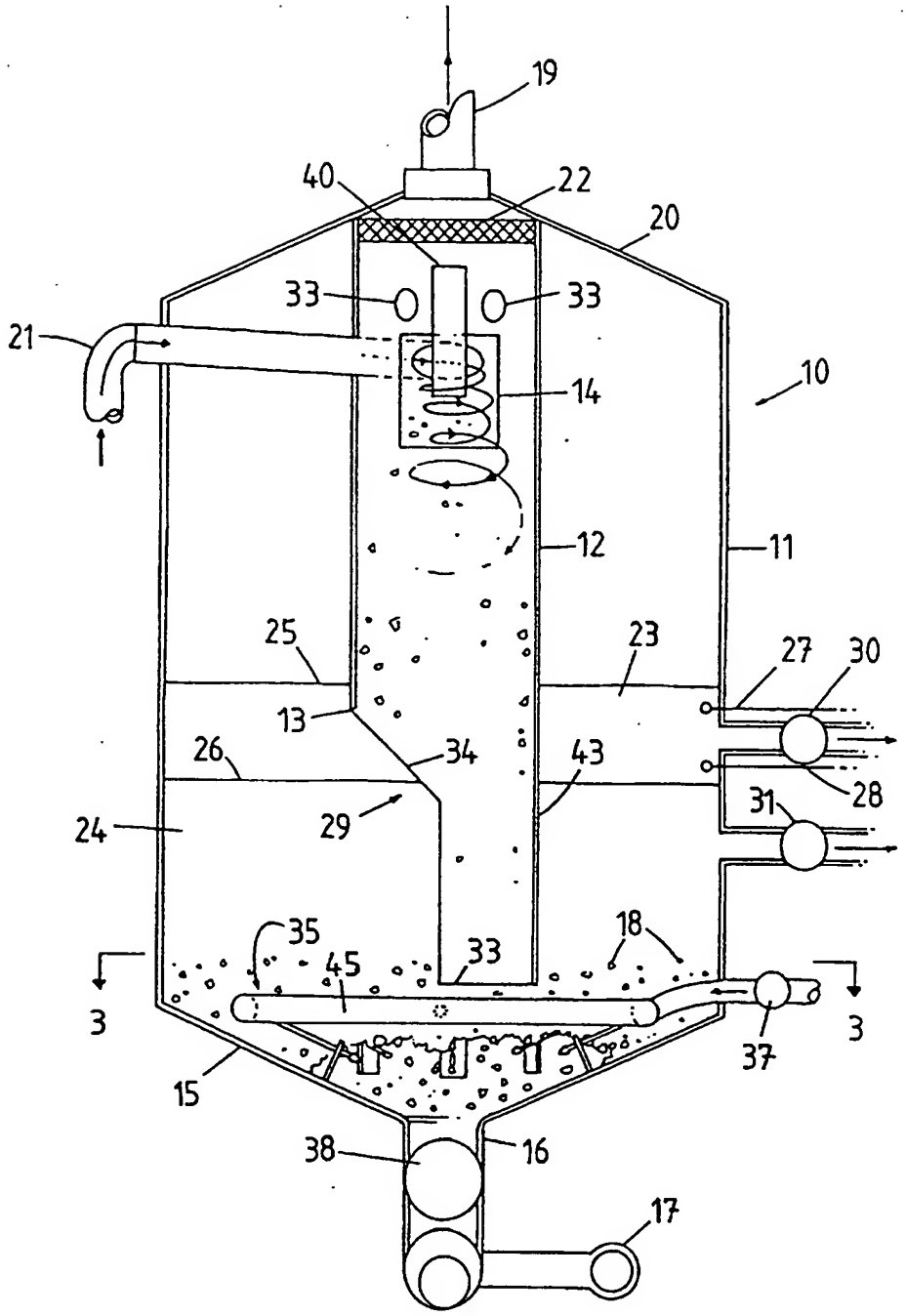
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FIG.2

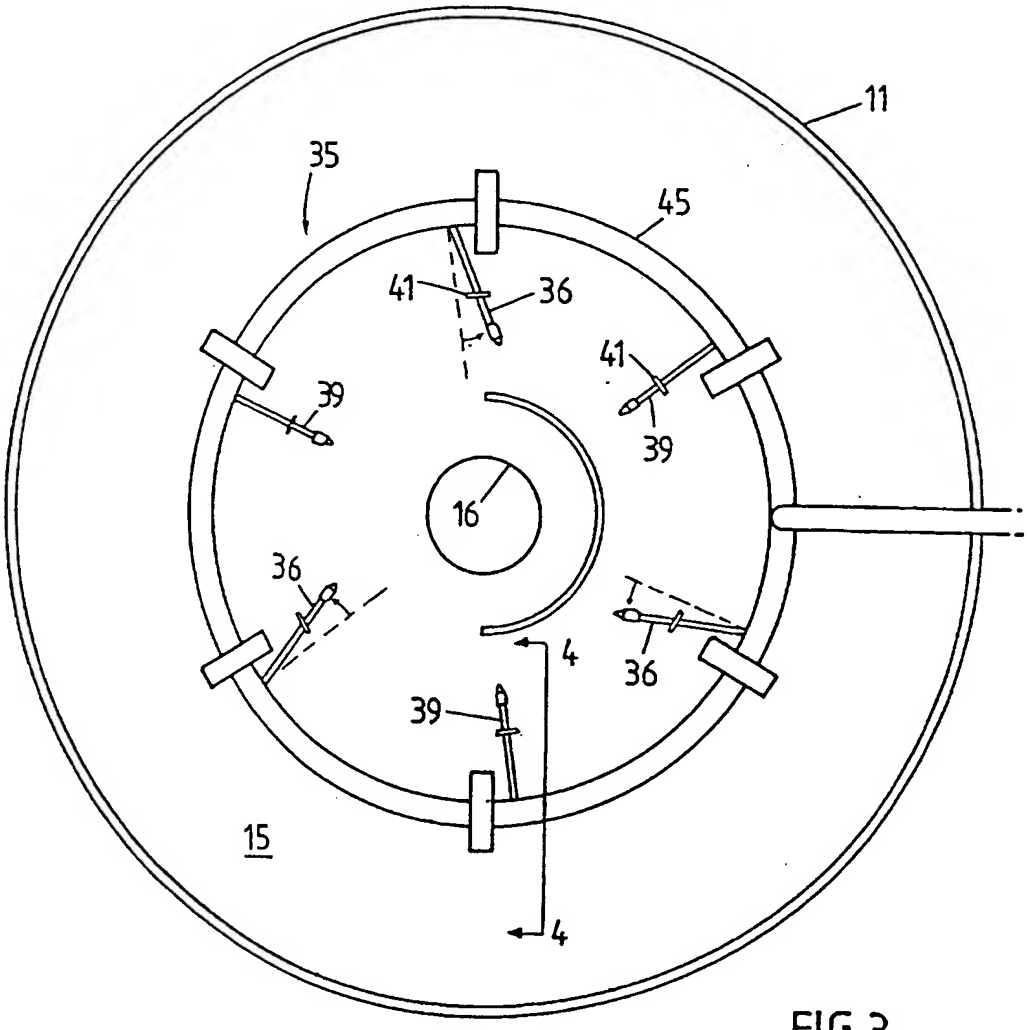

FIG.3

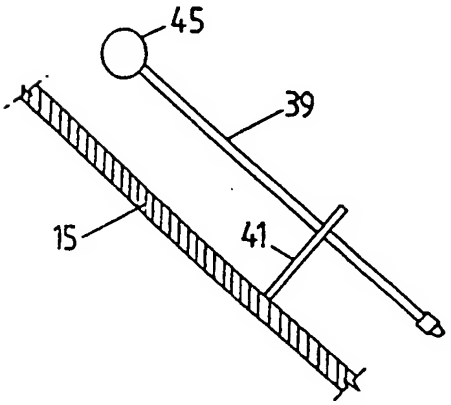

FIG.4

TITLE

"SEPARATOR FOR LIQUID HYDROCARBON, GAS, MUD AND SOLIDS AND METHOD OF SEPARATING LIQUID HYDROCARBON, GAS, MUD AND SOLIDS"

This invention relates to a novel means and method for separating gas, liquid hydrocarbon, mud/watery liquid, and drilled solid, from a supply containing some or all of such components.

BACKGROUND OF THE INVENTION

The production of gas or liquid hydrocarbon involves extracting a base product from a reserve well and separating out a target product from any impurities present in the base product. The use of a vertical separator which includes means for generating a cyclone to separate constituent elements has been well known for some time for the separation of liquids and gases. This type of separator is currently used in a production facility after a drilling operation has been carried out.

Pre-production environments require the drilling of a bore to the reserve where the desired product resides. Over balanced well drilling is a technique wherein the pressure from an underlying reserve is over balanced by the hydrostatic pressure of fluid material used to drill the well, which ensures that the well does not provide a flow of target product during the drilling process. Controlled under balanced well drilling, however, involves the flow of target product from the well during the drilling process. Under balanced well drilling techniques have significant advantages above those of over balanced well drilling techniques and can result in a reduction of well bore damage and thereby a significant production rate improvement from a reserve.

Over balanced well drilling techniques, which pre-date controlled under balanced well drilling techniques, generally involve the use of a watery fluid known in the art as "mud", one of the purposes of which is to provide the hydrostatic pressure necessary during drilling to prevent flow of target product from the well. Mud comprises water, clay particulate matter, and various polymeric compounds. During drilling, mud is pumped down into the well through the drill string and enters the well through the drill bit. The mud then rises back up the bore of the well carrying with it solid matter freed by the drilling process. The mud also acts to lubricate and cool the drill bit during the drilling process. Contaminated mud which returns to the surface from the well is cleaned and any impurities such as drilled solids separated out to enable the mud to be recycled back down through the drill string.

Under balanced well drilling techniques may also involve the use of mud. However, with this technique, the density and hence the hydrostatic pressure of the mud is reduced so that it is lower than the reservoir pressure by the introduction of an injection gas into the mud during the drilling process. The injection gas is introduced into the drilling fluid in the bore hole and percolates up through the mud to the surface. Injection gases generally used in this process are nitrogen or natural gas and it is not uncommon for the injection gas to be introduced at the rate of 30 to 40 cubic metres per minute. The reduction in hydrostatic pressure of the mud in the well bore allows the target product to flow during the drilling process and, as a result of this technique, the drilling fluid returning from the well comprises significant quantities of injection gas and target product (typically, liquid and gaseous hydrocarbon) in addition to solid matter freed during the drilling process. The gases, liquid

hydrocarbon and solid matter must be removed from the mud before the mud is recirculated down the drill string.

Currently, in under balanced well drilling operations, separation of contaminants from the mud is effected by the use of a horizontal separating cylinder which utilises an internal weir type arrangement. The internal weir type arrangement effects separation of target product, liquids and solids by gravity, and pumps are located at various points along the cylinder to pump out the constituent elements. Such separating cylinders are very large and heavy, and cannot be readily transported or used in confined spaces.

The invention described in this specification is not necessarily limited to under balanced drilling techniques, and could possibly be applied also to over balanced drilling techniques. However, this invention is particularly applicable to under balanced drilling techniques, since in under balanced techniques the drilled solids become entrained with the flow of watery liquids (mud), injection gas, and also target product which may be liquid hydrocarbon or gaseous hydrocarbon, and separation of these four phases constitutes problems, the most important of which is removal of gas and drilled solids from the liquids and also the separation of the liquid hydrocarbon from the watery liquids. This invention is directed to separation of the four phases, and to providing means to inhibit blockaging of the separator outlet.

PRIOR ART

In British Patent No. GB 2036606 in the name of Plenty, there is disclosed a cyclonic type of separator used in gas production (not drilling), the separator having a vertical axis and a base, and the gas being introduced into the cyclonic separator tangentially so that the gas swirls around an inner surface of a cylindrical wall of the separator.

Finely entrained liquid and any solid particles mixed with the gas are separated and deposited in the base of the cylinder. The separator in this patent is specifically directed to the release of liquid and solid particles from a gas product.

However, the separator disclosed in this patent is wholly unsuitable for separation of products produced during underbalanced drilling as it is a production tool, in that it is essentially a two phase separator for use in a production phase to separate small traces of liquid and solids from a target gas product. It is not capable of handling large amounts of particulate matter such as drilling cuttings, which would merely aggregate in the base of the cylinder, and would be very difficult to remove. It also has no facility for separating liquid hydrocarbons from watery liquids, which hydrocarbons are present in large quantities in under balanced drilling.

Also, such a separator as is disclosed in GB 2036606 would be unsuitable for use as more than a two phase separator during underbalanced drilling for separating liquid from gas, since the blockages which would occur due to solids separating from the liquids would render the separator useless.

Four phase separators are already known, but have generally been of the weir type. In a weir type of separator, gravity is the only force which will separate the gas, liquid hydrocarbon, mud and solids, and therefore it is necessary that the separator should be relatively large in physical size to maximise residence time. The large size results in high costs and, consequently, separators of this type are difficult and expensive to transport.

BRIEF SUMMARY OF THE INVENTION

One object of this invention, therefore, is to provide a separator which is capable of separating four phases, namely gas, liquid hydrocarbon, watery liquids and drilled

solids, and in an embodiment of the invention, there is provided a separator for separating material containing a gas component, a liquid hydrocarbon based component, a water based component and a solid component, said separator including a first substantially cylindrical portion, an inlet pipe in communication with and disposed relative to the said first cylindrical portion such that, in use, material flowing through the inlet pipe is caused to form a downwardly flowing cyclone in the said first cylindrical portion and thereby substantially separate the gas component from the water based component, the liquid hydrocarbon based component and the solid component and partially separate the water based component, the liquid hydrocarbon based component and the solid component from each other, a second substantially cylindrical portion substantially surrounding the said first cylindrical portion and extending below the said first cylindrical portion, the said second cylindrical portion receiving, in use, the water based component, the liquid hydrocarbon based component and the solid component from the said first cylindrical portion and effecting further separation of the water based component, the liquid hydrocarbon based component and the solid component from each other, and a vessel substantially surrounding the said second cylindrical portion for receiving and collecting, in use, the substantially separated water based component, liquid hydrocarbon based component and solid component.

As far as the aspect of separation is concerned, the passage of material from the borehole is initially subject to very high centrifugal force as it rotates within the first cylinder. The small size of the first cylinder ensures that the rotational velocity is very high, the centrifugal force being a function of the square of rotational velocity. A very high rotational velocity therefore will throw the solids (the most dense particles)

against the interior surface of the first cylinder, and the much lighter gas will be free to flow out of the top of the first cylinder to be dried in a demister prior to being discharged through a gas vent tube. The first cylinder is constructed so as to primarily separate out a substantial quantity of gas from the materials flowing from the borehole.

For separation of liquid hydrocarbon from watery liquids, the centrifugal force serves to break emulsions and partially separate the liquid hydrocarbon and watery liquid from each other as they pass through the first cylinder. As the flow passes out of the first cylinder, it sprays out to an inside surface of the second cylinder and the rotational and linear velocities rapidly diminish. As the liquid hydrocarbon, watery liquids and solids move down the inner surface of the second cylinder they still have some swirling motion which acts to further separate the liquid hydrocarbon, watery liquids and solids, this motion further diminishing towards the base as the components move through the second cylinder and into the vessel where gravity effects final separation of the components.

As said above, one of the main difficulties experienced with four phase separators has been the deposit and consequential blockage of solids at the solids outlet of the separator. It is of course desirable that the solid particles be released from a discharge pipe which is very much smaller in diameter than the main body. This requires a curved or conical base for the main body, the outlet being most conveniently located at the base of the cone or curved bottom of that body. With such an outlet there is a natural tendency for the solid particles to wedge against each other and "bridge" across the discharge outlet at the bottom of the main body. To overcome this, if it should occur, in an embodiment of the invention there is provided a circular sparging

ring provided with downwardly directed nozzles arranged in a configuration whereby the nozzles will tend to separate those particles which are closest to an inner surface of the conical base from those which would otherwise bridge. When liquid is pumped at high pressure and velocity through the nozzles, any tendency of the particles to bridge is prevented, and the particles become entrained in the liquid in the lower part of the main body. In this way, the solids are readily discharged through the solids discharge outlet. . The solid particles then pass into an inlet of a progressive cavity positive displacement pump which pumps the solids away for disposal.

BRIEF DESCRIPTION OF THE INVENTION

An embodiment of the invention will now be described with reference to, and as illustrated in, the accompanying drawings, in which:

Figure 1 is a plan view of a separator in accordance with the present invention with a portion of the separator partially cut away;

Figure 2 is a diagrammatic cross sectional view taken along line 2-2 of Figure 1 in the direction of the arrows;

Figure 3 is a cross sectional view taken along the line 3-3 of Figure 2 in the direction of the arrows; and

Figure 4 is a cross sectional view taken along the line 4-4 of Figure 3 in the direction of the arrows.

Referring to the drawings, there is shown a four phase separator 10 which is suitable for separating the output from a borehole during an under balanced type drilling operation (although it could be used in over balanced type drilling). The separator is capable of separating fluent material including a gas component, a liquid hydrocarbon based component, a water based component (consisting mostly or entirely of mud),

and a solid component, all of which are normally discharged from a borehole during under balanced drilling.

The separator 10 is provided with a first generally cylindrical portion in the form of a cyclonic device 14, a second generally cylindrical portion in the form of an internal cylinder 12 and a vessel in the form of a main body 11. The main body 11 includes the internal cylinder 12 depending from its upper end, the internal cylinder 12 having cylindrical walls down to a level 13. The internal cylinder 12 contains the cyclonic device 14. A lower part of the cylindrical walls of the main body 11 merge into a conical base 15, the conical base terminating at and being in communication with a downwardly directed discharge pipe 16. The discharge pipe 16 discharges into an inlet of a progressive cavity positive displacement pump 17 to discharge drilled solids 18 which are produced by the drilling bit, and introduced into the separator 10 in the under balanced technique.

The internal cylinder 12 is suspended by suspension means (not shown) from an upper end of a top closure portion 20 of the main body 11, and the upper end of the internal cylinder 12 may (but not necessarily) contain a moisture eliminator 22 which may be of conventional type. Support members (not shown) extending between an outer surface of the internal cylinder 12 and an inner surface of the main body 11 may also be provided for further supporting the internal cylinder 12 relative to the main body 11. The upper end of the internal cylinder 12 comprises a plurality of apertures 33 to allow residual gas percolating from the liquids in the main body 11 to pass into the internal cylinder 12 and thereby through a gas discharge outlet 19.

The cyclonic device 14 is generally centrally located within the internal cylinder 12, and an inlet pipe 21 delivers the product of a borehole tangentially (helically) into the

cyclonic device 14 so that the product swirls at a very high rotational velocity and a very high lineal velocity as it enters the separator. The cyclonic device 14 includes a vortex finder 40. The internal cylinder 12 is longer than the cyclonic device 14 and of larger diameter, and projects downwardly therefrom. The high velocity acts to quickly separate most of the gas (which may contain mostly nitrogen or natural gas introduced during the drilling process) from the solids, watery liquids and liquid hydrocarbon and also partially separates the watery liquids, the liquid hydrocarbon and the solids from each other. The gas moves upwardly through the vortex finder 40 in the cyclonic device 14, and the watery liquids, liquid hydrocarbon and heavier solid particles are sprayed outwardly from the lower end of the cyclonic device 14 against an inner cylindrical surface of the internal cylinder 12 whilst rapidly diminishing in both lineal and rotational velocity. As the liquid hydrocarbon, watery liquids and solids are sprayed against and move down the inner cylindrical surface of the internal cylinder 12, they still have some swirling motion which acts to further separate the liquid hydrocarbon, watery liquids and solids from each other. Part way down the internal cylinder 12 the watery liquids, liquid hydrocarbon and heavier solid particles encounter a cut away portion 29 having a curved portion 43 and a side opening 34 which extends between the level 13 and an end 33 of the cut away portion 29. The cut away portion 29 facilitates passage of the separated liquid hydrocarbon and watery liquids from the internal cylinder 12 to the main body 11 by virtue of the side opening 34. In this way, the cut away portion 29 allows the relatively light liquid hydrocarbon to leave the inner cylinder 12 without being forced down to level 13. At the same time the cut away portion 29 acts as a guide to direct the solids into the conical base 15. Further separation of watery liquids, liquid hydrocarbon and solids also takes place as

they pass down the curved portion 43 and into the base 15 of the vessel. At this stage, the components will have lost most, if not all, of their circular motion. The substantially separated liquid hydrocarbon and the watery liquids collect in the main body 11 so that the liquid hydrocarbon 23 has an upper level 25 and an interface 26 with the watery liquid 24. The levels 25 and 26 are maintained respectively by sensors 27 and 28 which automatically actuate valves 30 and 31 respectively to discharge the separated liquid hydrocarbon to storage and recirculate the watery liquids from the main body 11 under the operating pressure of the separator.

During the downward passage of the material, the solids 18 being the densest will settle out in the conical base 15 above the discharge pipe 16, and if the base 15 or pipe 16 become blocked, the particles 18 can again become entrained in the liquid by use of sparging means, in this example a substantially tubular sparging ring 35. The sparging ring 35, shown more particularly in Figures 3 and 4, includes six nozzles 36, 39 which are as illustrated and which are directed downwardly from a main body 45 of the sparging ring 35, three of the nozzles 36 being directed in a spiral fashion and the other three nozzles 39 being longer, directed radially inward and adjusted to an optimum direction to avoid bridging. Each nozzle 36, 39 is supported by a link 41. The sparging ring 35 is charged with liquid from the watery liquids outlet, and a pump 37 directs the liquid through nozzles 36, 39 with pressure and velocity such that the generated turbulence entrains the solid particles 18 and thereby prevents the particles from bridging across the opening of the discharge pipe 16. In this way, the sparging ring 35 ensures that the solid particles 18 flow through the pipe 16 when valve 38 is open.

In addition to the sparging ring 35, the pump 17 is effectual in transporting solids 18 away from base 15. The pump 17 is preferably of the progressive cavity positive displacement type.

The combination of high centrifugal force and quiescent residence of the watery liquid and liquid hydrocarbon results in an excellent release of gas with very little gas retained in the liquids. The existence of the sparging ring 35 and its associated pump 37 is sufficient to satisfactorily ensure that the drilled solids 18 are removed from within the main body 11.

The valve arrangement will be seen to be extremely simple, and use can be made of quick action connectors with the various pipes. There is usually no requirement for operator control, since the operation of the separator of this invention is generally automatic.

In this invention, the active mode of operation uses energy from the gases and liquids emanating from the well. This enables the separator to be smaller than the weir type which are passive in operation and rely upon gravity to separate liquid hydrocarbon, water and solids. The passive mode of operation of the horizontal weir type of separator requires relatively long periods of residence time within the separator for the gravitational effect to separate out the constituent elements. This in turn necessitates a larger vessel size. As the vertical separator of this invention separates the constituent elements actively by using the energy of the flow from the borehole, it achieves a similar separation rate as compared with a horizontal separator with an apparatus which is significantly smaller and lighter in weight. This is particularly important in off shore drilling, or drilling in remote areas where space is at a premium and available lifting capacity is limited.

Modifications and variations as would be apparent to a skilled addressee are deemed to be within the scope of the present invention.

CLAIMS

1. A separator for separating material containing a gas component, a liquid hydrocarbon based component, a water based component and a solid component, said separator including a first substantially cylindrical portion, an inlet pipe in communication with and disposed relative to the said first cylindrical portion such that, in use, material flowing through the inlet pipe is caused to form a downwardly flowing cyclone in the said first cylindrical portion and thereby substantially separate the gas component from the water based component, the liquid hydrocarbon based component and the solid component and partially separate the water based component, the liquid hydrocarbon based component and the solid component from each other, a second substantially cylindrical portion substantially surrounding the said first cylindrical portion and extending below the said first cylindrical portion, the said second cylindrical portion receiving, in use, the water based component, the liquid hydrocarbon based component and the solid component from the said first cylindrical portion and effecting further separation of the water based component, the liquid hydrocarbon based component and the solid component from each other, and a vessel substantially surrounding the said second cylindrical portion for receiving and collecting, in use, the substantially separated water based component, liquid hydrocarbon based component and solid component.

2. A separator as claimed in claim 1, wherein the said second cylindrical portion includes at an end thereof remote from the said inlet pipe a cut away portion including a curved portion and an opening portion, the opening portion of the cut away portion facilitating passage of the liquid hydrocarbon based component and the

water based component from the said second cylindrical portion to the said vessel and the curved portion of the cut away portion acting as a guide for the solid component.

3. A separator as claimed in claim 1 or claim 2, further including a sparging means located adjacent and upwardly of a solids discharge aperture of the vessel, the sparging means being adapted to receive fluid under pressure and direct the fluid towards the discharge aperture so as to substantially prevent blockaging of the discharge aperture.

4. A separator as claimed in claim 3, wherein the sparging means includes a tubular annular member and a plurality of nozzles in fluid communication with the annular member and configured so as to direct said fluid generally towards the discharge aperture.

5. A separator as claimed in claim 4, wherein at least one of the nozzles is aligned so as to direct said fluid towards the discharge aperture in a direction substantially radially of the discharge aperture.

6. A separator as claimed in claim 4 or claim 5, wherein at least one of the nozzles is aligned so as to cause said fluid to follow a substantially spiral path towards the discharge aperture.

7. A separator as claimed in any one of claims 4 to 6, wherein the said plurality of nozzles include three first nozzles aligned so as to direct said fluid towards the discharge aperture in a direction substantially radially of the discharge aperture and three second nozzles aligned so as to cause said fluid to follow a substantially spiral path towards the discharge aperture, each first nozzle being circumferentially disposed on the sparging ring intermediate two second nozzles.

8. A separator as claimed in any one of the preceding claims, further including sensing means for sensing the respective levels of liquid hydrocarbon based component and water based component in the vessel and automatically actuating respective discharge valves in response to the said levels to discharge the liquid hydrocarbon based component and water based component from the vessel.

9. A method of separating material containing a gas component, a liquid hydrocarbon based component, a water based component and a solid component, said method including the steps of causing the material to form a downwardly flowing cyclone in a first substantially cylindrical portion and thereby substantially separating the gas component from the water based component, the liquid hydrocarbon based component and the solid component and partially separating the water based component, the liquid hydrocarbon based component and the solid component from each other, providing a second substantially cylindrical portion substantially surrounding the said first cylindrical portion and extending below the said first cylindrical portion for receiving, in use, the water based component, the liquid hydrocarbon based component and the solid component from the said first

cylindrical portion and effecting further separation of the water based component, the liquid hydrocarbon based component and the solid component from each other, and collecting the substantially separated water based component, liquid hydrocarbon based component and solid component in a vessel substantially surrounding the said second cylindrical portion.

10. A method of separating material as claimed in claim 9, further including the steps of providing a sparging means located adjacent and upwardly of a solids discharge aperture of the vessel, pumping fluid under pressure into the sparging means and directing the fluid towards a discharge aperture of the vessel so as to substantially prevent blockaging of the discharge aperture.

11. A method of separating material as claimed in claim 10, further including the step of pumping said fluid through a tubular annular member of the sparging means, the tubular member having a plurality of nozzles configured so as to direct said fluid generally towards the discharge aperture.

12. A method of separating material as claimed in claim 11, further including the step of aligning at least one of the nozzles so as to direct said fluid towards the discharge aperture in a direction substantially radially of the discharge aperture.

13. A method of separating material as claimed in claim 11 or claim 12, further including the step of aligning at least one of the nozzles so as to cause said fluid to follow a substantially spiral path towards the discharge aperture.

14. A method of separating material as claimed in any one of claims 10 to 13, further including the steps of providing three first nozzles aligned so as to direct said fluid towards the discharge aperture in a direction substantially radially of the discharge aperture and providing three second nozzles aligned so as to cause said fluid to follow a substantially spiral path towards the discharge aperture, each first nozzle being circumferentially disposed on the sparging ring intermediate two second nozzles.

15. A method of separating material as claimed in any one of claims 9 to 14, further including the step of sensing respective levels of liquid hydrocarbon based component and water based component in the vessel and automatically actuating respective discharge valves in response to the said levels to discharge the liquid hydrocarbon based component and water based component from the vessel.

16. A separator substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

17. A method of separating material substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

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INVESTOR IN PEOPLE

Application No: GB 9823630.0 **Examiner:** Neil Franklin
Claims searched: All **Date of search:** 26 March 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): B1D (DPPA) B1T(TPPA) B2P

Int Cl (Ed.6): B04C 9/00 E21B 21/06, 43/34

Other: Online: EPODOC, PAJ, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	US 5 522 999	(BROUSSARD) See whole document	1,9 at least
X	US 5 492 622	(BROUSSARD) See whole document	1,9 at least
X	US 5 407 584	(BROUSSARD, SR) See whole document	1,9 at least
X	US 5 300 222	(BROUSSARD, SR) See whole document	1,9 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.